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Report V
Review of Soil Stabilisation Methods

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Appropriate and Efficient Maintenance of Low Cost Rural Roads

Report VI
Report V: Review of Soil Stabilisation Methods

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EXECUTIVE SUMMARY

OBJECTIVES OF THIS ELEMENT OF THE PROJECT

Extract from the Research Proposal

This element involves a review of the use of fibrous and chemical (synthetic) stabilisers during road maintenance. A system to categorise materials and identify suitable additives for study will be conducted. A detailed laboratory study will be conducted in the UK using these materials and methods. Some overseas laboratory testing will be conducted where possible. Laboratory and full scale trials expect to reflect both the actual methods of repair used in practice, and the effect of alternative methods as well as in the interaction between material and method. An aim of the tests will be to produce a material which can be used for filling potholes, ruts or shoulders which will gain strength with modest compaction and establish some adhesion to the surrounding ground or original construction.

Whilst some testing of man made fibres will be included, the aim will be to identify natural, local fibres which could be used. If the use of man made fibres shows promise, then more effort will be put into locating and testing natural fibres.

The chemical stabilisation of marginal materials in areas of low material resources is being considered and tested on two of Roughton International's rural roads maintenance projects (Uganda and Nepal) and are expected to be of value to this project. Material recycling by using alternative additives as well as the more traditional lime and cement will be investigated.

An analysis will be conducted as to the usefulness and effectiveness of these methods and a recommendation of standards will be put forward to Progress Review Group. The final conclusion of this element will form a stand-alone report as well as part of the final guidelines for rural road maintenance.

Very early in the research it was realised that there was a lack of independent research information about these products. It was therefore agreed that only a database and notes for users should be produced for chemical stabilisers. It was agreed that standards would not be produced (as noted in the last paragraph).

Summary of the Work

Over the two years project programme only six months were available for the work on chemical soil stabilisers, review of case studies and fibre reinforced soils. This work was split into three parts:

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The first part of this element of the research concentrated on synthetic stabilisers. One of the objectives of the research was to form simpler methods of assessing the use of these stabilisers in the field. This could not be achieved due to great lack of independent research information and this research programme was too short to undertake detailed research for preparing simplified assessment methods. It was therefore decided to review the available information about these stabilisers, form a users guide and a database consisting of product composition, soil types for which they may be used, environmental issues and brief review of case studies. Thirty-eight products were reviewed for this part of the study.

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The second part of this element of the research concentrated on case studies. Two detailed reviews were conducted. Case study 1 related to the use of an enzyme stabiliser, UBIX 10, in Nepal for the construction of a mountain road. A researcher visited Nepal to observe the trials. He also undertook some monitoring tests to evaluate the success of the stabiliser.

Case Study 2 related to assessment of causes of failure of a trial section of road, stabilised with Terra-fix, constructed in Seychelles. This road failed (pot holes started to appear) a few years after construction. Field and laboratory test results from the trial construction were reviewed. Some laboratory tests were also conducted during this research to understand the causes of failure.

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The third part of this element of the research concentrated on the use of fibres for stabilising soils. This included both synthetic and natural fibres. Laboratory work was conducted on polypropylene fibres and both laboratory and field trials were conducted sisal fibre (natural fibre). Much of the work on using fibres was conducted in Uganda by the Ministry of Transport, Communication and Public Works. A field trial comprising construction of a road section was conducted on fibre reinforced laterite in Uganda.

The effect of three lengths (6, 12 and 18 mm) of polypropylene fibres at concentrations ranging from zero to 0.6% on the density, compressive strength and CBR of Oxford clay were investigated. The effect on density, UCS and CBR of 12 mm long sisal fibres ranging in concentrations from zero to 0.6% was investigated for laterite soil stabilised with lime and cement. The latter were at both 4 and 6% concentrations. Four, ten metre long section of road were constructed with reworked laterite, lime stabilised laterite and fibre reinforced and lime stabilised laterite. In the trials 12 mm long (nominal length) sisal fibres at 0.2 % concentration, and 4% lime were used.

The fibre reinforced cement stabilised study was a pilot investigation to assess suitability of this material for pothole repair. The effect of fibres on dry density, UCS and CBR were measured. A field trial was conducted in Uganda on repairing potholes with fibre reinforced cement stabilised lateritre.

Results of the Research

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The first part of this element of the study on stabilisers has clearly shown that there are a range of stabilisers that fall into two broad categories: sulphorated petroleum products and enzymes. The review of these products show that significant cost savings can be made if they are applied in the correct context. Discussions with practitioners show that failures can occur and these are due mainly to improper use of the stabilisers.

The database of 38 products provides an insight into the range of products. It is clear that the products are supported with different levels of information. Some care is therefore required in selecting a suitable stabiliser. The database allows a preliminary assessment of the stabilisers to be made. It also includes email and web site addresses. This database is available on compact disc.

Although all the manufacturers claim that savings could be made in the cost of construction and maintenance. It was difficult to make any judgement about this as costs would depend on the quantity of product used and where and how it was delivered.

General guidelines have been produced for using both sulphonated products and enzyme stabilisers.

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The second part of this element of the study on case studies shows that in the first case of a trial in Nepal failure occurred due to improper use of construction equipment and procedures. A report on the trial was sent to the manufacture for comment. He responded by saying that it would have taken a miracle for the stabiliser to work. He has however, offered to supply the product free of charge should it be possible to run another trial. Although the manufacturer's representative was present on site, the stabiliser was applied incorrectly with improper construction procedures.

For the second case study where a road was stabilised in Seychelles failure is thought to have occurred due to improper construction procedure. Suppliers or manufacturer of Terrafix could not be contacted to comment on the findings of the investigation.

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The third part of this element of the study on fibres showed that it was possible to use synthetic fibres to stabilise soils. They were however expensive. Work on sisal reinforcement showed potential and although a field trial on a road section worked well, it did not achieved its maximum potential as it was not possible to construct the road properly with the resources available. Nevertheless, it was shown that a poorly constructed fibre reinforced lime stabilised section performed as well as a well constructed lime stabilised or fibre reinforced road section.

Potholes trials showed that fibre reinforced cement stabilised laterite could be used to make repairs.

Implication of the Research

The results of the first part of the study did not achieve the objectives entirely due to lack of independent research information and lack of time to undertake extensive laboratory testing under the current programme. However, a general guidance note was prepared for using these stabilisers. A database that identifies at-a-glance the available products and some basic information about them was prepared. This included list of addresses and product names. This should enable the user to obtain more recent information about the products.

The two case studies have shown the pitfalls of using inappropriate construction equipment and procedures.

The work on fibre reinforced soils meets all the objectives set in the proposal. In the limited period of research it was possible to show that natural fibres may be used in road construction and pothole repair.

Recommendations and Future Work

This research project has uncovered a large quantity of information about chemical stabilisers. Most of this was however, supplied by the manufacturers promoting their products. There is a need to undertake independent research to evaluate the products. The results of the research will help the engineer to make objective decisions about the use of particular stabilisers.

A database of products showing soils for which they are best suited was prepared. However, there is a need to update the database to ensure that products that have proved unsuccessful in certain situations are highlighted and new ones are added. This information could be available on computer disc for distribution. Information about this could also be available on the Internet.

This work would be undertaken at the University of Birmingham with Roughton International. The former would be using their expertise already developed in this area and Roughton International would provide contacts and help to ensure that the database is end-user friendly by inputting the practitioners view.

This research has shown that fibres can be used to successfully reinforce soils for the construction of roads. The full potential of the field trials was not fully realised because suitable construction equipment was not available. It is therefore recommended that a larger research programme be undertaken to evaluate the fuller potential of using fibres in road construction. It is recommended that a laboratory study is followed by at least one field trial. In parallel with this it is proposed to develop low technology equipment excavating existing gravel roads and mixing in fibres. It is strongly recommended that bulk of this work is undertaken abroad. The University of Birmingham and Roughton International in collaboration with perhaps the materials laboratories in Uganda and Botswana and an equipment manufacturer would best conduct this research. The field trials could be conducted at one of Roughton International's contracts.

This proposed research would need to be for a three-year duration as field trials would need to be monitored for a prolonged period to assess durability of the stabilised soils.

Pilot study on pothole repair has also shown some potential. It is therefore suggested that this work is developed further in terms of a detailed laboratory investigation and field trials. It is suggested that this work is conducted in parallel to the study discussed above by the University of Birmingham, Roughton International and one or more overseas countries where fieldwork may be conducted.

Information from both the above studies would be presented at regional conferences so that it would be available to the users. Extracts of the report would also be published on the Internet.

REPORT V - REVIEW OF SOIL STABILISATION METHODS

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REVIEW OF SOIL STABILISATION METHODS

1. INTRODUCTION

Since about the mid fifties a number of soil stabilisers based on sulphonated hydrocarbons and enzymes have been developed for stabilising soils mainly for use in road construction. These stabilisers enable marginal soils to be used. Up to about the late 70's only a limited number of such products were available. However, in the recent past a large range of products have appeared on the market. All the suppliers claim a high degree of success with their products. But, in practice the success of using these compounds seems to be variable.

During this research a number of sources of information were investigated. These sources included learned journals, manufacturers and suppliers of these stabilisation compounds. Much of the information was however gleaned from the Internet web sites of suppliers or manufacturers. In most cases further enquiries were made about the products and in many instances no replies were received. In some cases however, there was good co-operation.

Earlier on in the project a general enquiry was sent out on the Internet to the "Geotech Mailbase" about the use of these stabilisers. Replies were received from a handful of practising engineers. Without fail their experiences were not positive. This was in contrast to the case studies submitted for our perusal by many product suppliers. They were all positive and showed that considerable benefits were to be had from using these stabilisers. They show both an economic and environmental benefit.

It should be noted that very little independent information regarding the use of these products was found. In view of this, the study concentrated on gathering information about the products and their uses. A database of the 38 products was compiled and is included as part of this report in an appendix in electronic format on compact disk. Also included is a database of manufacturers and suppliers.

This work was undertaken at the University of Birmingham.

Stabilisation of soils using lime, cements and bituminous materials are not described in this report.

2. REPORT STRUCTURE

Section 3 of the report describes background information about the stabilisers. Section 4 deals with sulphonated petroleum products and enzyme stabiliser types their properties and uses. Section 5 of the report describes the database, which is included in Appendix I. A database of addresses of manufacturers and suppliers is given in Appendix II.

3. BACKGROUND

Increasing need to reduce costs, conserve materials and use poorer soil quality materials have resulted in the use soil stabilisers in increasing quantities in the construction of roads.

Traditional materials such as lime and cement have been researched extensively. However, chemical stabilisers have been developed in the last thirty or so years have not been researched extensively. Nevertheless they offer the attraction of using smaller quality of stabiliser (compared to lime and cement). The manufacturers provided most of the information about these stabilisers. Some independent research is underway at CSIR. Paige-Green and Coester (1996) researched into the use of sulphonated petroleum products at CSIR concluded that provided these stabilisers were used in the correct context, significant cost savings could be achieved in low volume road. They emphasised that a properly controlled construction and quality control procedure was required for successful stabilisation. This was also found to be the case for enzyme based stabilisers as shown in Part 2 of this report on Case Studies, where failure of road was attributed to poor construction procedures and quality control, amongst other factors.

In 1995 Bagonza reported on Uganda's experience of Conaid-treated roads comprising weathered silty clay (Liquid limit 60%, Plasticity Index 30% and 70% passing 75 µɱ sieve). He concluded that roads stabilised with Conaid proved to be cost-effective in terms of construction and maintenance. On the basis of this successful trial the use of Synthetic soil stabilisers was included in the General Specifications for Roads and Bridge Works by the Ministry of Works, Transport and Communications in Uganda.

More recently Scher (1999) advocated increasing use of these stabilisers to improve marginal materials. He reports that the use of Consolid products for stabilising waste materials from quarries in road construction.

Although only a few references are reviewed above most of the information was in the form of private correspondence and web-sites. The latter was reviewed and its outcomes are reported in the following sections without many specific references as the products have been grouped into categories.

4. STABILISER TYPES

A number of products are marketed as soil stabilisers. Some of these are dust palliatives, some are compaction aids and others are binders. This report is about compaction aids and binders. The two main types are described below.

4.1 Sulphonated Petroleum Products

These are sometimes also referred to as sulphonated hydrocarbons. The title describes the main active ingredient, but the stabiliser contains a number of other ingredients which all aid the action of the compound in some way. Sulphonated Petroleum Products (SPP) are essentially surfactants. The main agent is a two-part molecule. One part is absorbed onto the surface of clay particle and reduces its ion exchange capacity. This results in inability of the clay mineral to absorb water, thus changing it from hydrophilic to hydrophobic in character. The other component acts as a lubricant that enable particles to move past each other with reduced effort. Thus, with SPP greater dry density should be achieved for a given compactive effort compared to plain soil.

SPP based product is thus a compaction aid, not a binder. Changes in behaviour of the material are purely from the waterproofing action of the compound and the increased density that results from ability of the particles to pack together more closely. The final result is that the treated soil is less moisture sensitive and should exhibit better engineering performance.

4.1.1 Improvements in properties of materials

Increase in density and reduction in cation exchange capacity can result in the following improvements:

- reduction in plasticity index
- reduction in optimum moisture content
- reduction in swell and linear shrinkage
- increase in maximum dry density
- increase in unconfined compressive strength, CBR and stiffness
- decrease in permeability

Improvements in engineering properties should be immediate. However, greater enhancements may be achieved, as moisture is lost through evaporation. Generally these products may be used in environments where the evaporations rates are high. Some products such as CONSOLID can work in high humidity environments due to water absorption capacity of components of the stabiliser.

4.1.2 Materials

From the reaction described above it is clear that these products react with clay. or clay type particles. It is thus essential that this fraction is present in the soil to be treated. General requirements for suitable soils are given below.

- Soils should contain greater than 12% material finer than 0.075 µm.
- Soil should have a good range of particle size distribution and should be well graded.
- Clean sands and gravels cannot be stabilised.
- Organic soils with medium to high plasticity cannot be stabilised.
- It may be possible to treat low plasticity organic silts.

4.1.3 Pre-stabilisation Tests

Suppliers provide varying degree of guidance regarding tests on soils to ascertain their suitability for stabilisation. A general review of literature suggests that the following tests should be conducted:

Soil Description

A good soil description will give an initial indication regarding the suitability of the soil for stabilisation. Key features of the description should be identification of the fines content, particle size distribution, presence of organic matter and consistancy of the material.

Particle Size Distribution

If more than about 15% material is smaller than 0.075 µm then a sedimentation test should be conducted to ascertain the distribution of particles in the silt range of sizes. A well-graded soil is likely to be better suited for stabilisation.

In-situ Moisture Content

This will be used to calculate the amount of water that may be added to the soil to bring it to its optimum moisture content.

Organic Content

Sulphonated petroleum products are not generally considered to be suitable for soils containing organic matter. However, there appears to no guidance regarding the acceptable limits of organic matter.

pH Determination

This will give a measure of acidity of the soil and will give a reference value to compare with when stabiliser is added.

Liquid and Plastic Limit Determinations

These tests will help to identify the nature of the fines present in the soils. Results may also indicate the presence on organic matter.

Dry Density and Moisture Content Relationship

The results of these tests will gives target values for density and moisture content.

X-Ray Diffraction

Only a few manufacturers suggest that this test is conducted.

CBR and UCS

If the soil is likely to be suitable it is then suggested that CBR and UCS tests are conducted at moisture contents ranging from Optimum Moisture Content (OMC) minus 2% to OMC plus 2%. These may be used as reference values.

4.1.4 Application Rate

Application rates of sulphonated petroleum products range from 0.06 l/m^3 to 0.8 l/m^3. Typical application rates for four stabilisers are given in Table 4-1. Because of the large range it is strongly recommended that the supplier is consulted to select the most appropriate rate of application. When selecting application rates tolerance in application rate should also be determined.

Table 4-1 Sulphonated Petroleum Products Stabiliser:Soil Ratios

Stabiliser	Amount of Stabiliser to be Added (stabiliser:soil) Range (l/m^3)
CBR Plus	0.06 to 0.18
Conaid	0.4 to 0.8
RRP 235	0.2 to 0.3
Terrabond	0.36 to 0.54

These products are normally supplied in concentrated from. Therefore, before application they have to be diluted with clean water. Generally the dilution rate range from 1:50 to 1:350 (concentrate:water ratio). The degree of dilution will depend on soil type. As each product is slightly different it is strongly recommended that advice is sought from the suppliers.

5. APPLICATION AND CONSTRUCTION PROCEDURE

Procedure for using the stabiliser is straightforward and is outlined below.

i. Area to be treated is cleared of all the organic material and is trimmed approximately to its final shape.

ii. If the moisture content is lower than the optimum then scarify the surface to a predetermined depth. Usually depth of treatment ranges between 150 to 200 mm. Before adding any water, gravel larger than about one third the thickness of the treated layer (larger than about 50mm) should be removed.

iii. If the moisture content is higher than optimum then it may be necessary to add drier material to reduce the moisture content to about 2 % below the optimum moisture content. Dry soil should be mixed and the surface should be trimmed to its approximate final shape. It should then be scarified to the required depth.

iv. If the moisture content is more than about 2% lower than the optimum then a proportion of the total water content required to bring it to its optimum may be added. Soil should be mixed thoroughly so that there is an even distribution of moisture through its entire depth.

v. The remaining water should be mixed with the stabiliser and added to the soil such that the required amount is distributed evenly across the surface.

vi. Mix the soil immediately to get an even distribution of the stabiliser throughout its depth.

vii. Treated surface should be trimmed to its final form and compacted as soon as possible after mixing to prevent loss of moisture.

viii. Check in-situ compaction across the treated area. If the soil has not reached the design value of dry density then further compactive effort should be applied immediately. Delay in application of compaction may mean that moisture is lost through evaporation and migration, and application of further compaction at a lower moisture may not result in an improvement in dry density.

ix. Final road surface should be shaped to prevent any ponding of water.

Treated road may be opened to traffic immediately after completion as the stabilisation effect is immediate. It does not require any curing. Furthermore it may benefit from secondary compaction from traffic loading.

6. GENERAL DISCUSSION

The success of the soil stabilisation depends on a number of factors. These are discussed below.

Ideally the soil to be stabilised should be well graded with at least 12% of material finer than 0.075 µm. Particle sizes should range from sub 0.002 µm (clay) to about 50 mm (gravel). The presence of clay particles is essential as the sulphonated products react with them. It may be necessary to add finer material to improve the particle size distribution. The dose of the stabiliser depends on the clay content. It is therefore essential that representative samples are tested.

The application of the stabiliser should be undertaken in a very controlled manner. Both under and over dosing may result in poor performance. It is not clear from literature if there are any acceptable tolerances in application rate. However, there is some "hearsay" evidence that overdosing may result in slipperier road surface when wetted.

Sulphonated products are a compaction aid. Thus, strength gain should be immediate. However, as, noted earlier some of the improvement is derived from evaporation and possibly from secondary compaction from traffic. It is therefore suggested that test procedures should be modified to reflect the field conditions. There is also some evidence that suggests that laboratory tests do not represent field performance. Discussions with some practitioners have indicated that sometimes laboratory tests show that the stabiliser does not perform. However, field trials show that it does. Therefore, further work is required to design appropriate testing conditions. These could include sealing the sides of the samples to prevent lateral movement of moisture, but permitting water to evaporate at the top. It could also include application cyclic load to specimen confined in a mould simulating secondary compaction. Curing temperature and humidity should also reflect field conditions. The additional testing described above will require elaborate equipment and test procedures. It is thus suggested that further research is conducted to firstly develop suitable test procedures so that the behaviour of soils treated with stabilisers can be understood more fully. Secondly research is required to develop some index tests that will give a measure of field performance of the stabilised soil.

In view of the difficulty of undertaking laboratory tests, which can simulate field conditions it is strongly recommended that a small field trail should be conducted to evaluate the stabiliser. Changes in moisture content, CBR, and loss of material from the surface should be measured over at least a wet and a dry season.

The manufacturers or suppliers made most of the information available for this study. Judging by the number of products and outline case studies presented it seems that these products work. However, there is a need to develop an envelope of soil types and conditions for their application. It is therefore suggested that further work should be done in this area.

7. EXAMPLES OF SULPHONATED PRODUCTS

Soil stabilisers identified as sulphonated products are listed below.

- CONAID (and CBR-PLUS)
- CONSOLID
- CONDOR
- ISS2500
- RRP 235
- Pennzsupress

Further detailed information about them is given in Appendix I.

7.1 Enzyme Based Stabilisers

The enzymes react with the organic matter (humic matter) in the soil to form cementitious material. This reaction commences almost immediately and it is thought that under the right environmental conditions about 90% of the reaction may be complete within the first 72 hours. Initial reaction product is a formation of a gel, which crystallises to form bonds, which hold together particles. Loss of moisture by evaporation is essential for the crystallisation of gels. The reaction is at micron level and the presence of finely divided humic matter and clay-sized particles is essential. Presence of clay is essential as the bonds formed bind this size of particle.

Surfactants in these compounds reduce the surface tension and enable better packing of these particles. The enzymes and organic material also result in the production of slime. This lubricates the particles and for a given effort enables greater density to be achieved compared to untreated material.

Enzymes are biodegradable and start to degrade within a short time of adding to a soil. Some Enzyme manufacturers claim that within about 72 hours more than 90% of the unreacted product can be degraded.

7.1.1 Improvements to soil properties

Enzyme based stabiliser aids compaction and forms cementatious bonds. It is estimated that the following improvements can result for the suitable soil types:

- increase in density
- improvement in strength
- increase in CBR
- reduction in shrinkage and swell
- enhancement in frost resistance
- decrease in permeability

Improvements in these properties can take up to 72 hours to occur. As for sulphonated products evaporation is necessary for these stabilisers to work. Thus they can only be used in warmer climates during dry seasons when evaporation rate is likely to be high.

7.1.2 Materials

Enzymes react with the organic matter in the soil to form hydrogel. The crystallisation of the gel results in the formation of the bonds. Thus soils need to contain some organic material. However, the required organic matter can comprise decayed material in the form of humic material.

7.1.3 Pre Stabilisation Testing

All the manufacturers stipulate that soil classification tests should be conducted to assess suitability of the compound. The range of tests stipulated by four of the many stabilisers are shown in Table 7-1. [*The stabilisers listed in Table 2 were chosen the basis of available information and not on their effectiveness as stabilisers. More information about these and other enzyme stabilisers can be found in the database in Appendix I of this report*.]

Table 7-1 Classification Tests Suggested by some of the Enzyme Stabiliser Manufacturers

Stabilser	Moisture Content	Particle Size Distribution	Liquid Limit	Plastic Limit	Shrinkage Limit	Maximum Dry Density	Optimum Moisture Content	pH
Endurazyme	✔	✔	✔	✔	✔	✔	✔	
Road Tech 2000	✔	✔	✔	✔		✔	✔	✔
Terrazyme	✔	✔	✔	✔		✔	✔	✔
UBIX 010	✔	✔	✔	✔		✔	✔	

As soils are variable materials it is strongly recommended that the following tests should be conducted on materials from each location.

i. Soil Description

A good soil description will give an initial indication regarding the suitability of the soil for stabilisation. Key features of the description should be identification of the fines content, particle size distribution, presence of organic matter and consistency of the material..

ii. In-situ Moisture Content

This will enable comparison with optimum moisture content (OMC) and thus determination of the amount of water required to bring the soil to its OMC. Generally if the soil is wetter than its OMC these stabilisers cannot be used.

iii. Dry Density Moisture Content Relationship

Results will enable determination of maximum dry density and OMC. A percentage of the maximum dry density is used a target for field compaction.

iv. Liquid Limit and Plastic Limit

Results will enable assessment of clay type to be made. Some stabiliser manufacturers' stipulate a minimum Liquid Limit or Plasticity Index.

v. Particle Size Distribution

All the manufacturers stipulate that the soil should be well graded and that missing range of particles should be made good. Almost all manufacturers state a minimum requirement for clay content.

Typical minimum requirements for clay content or an indirect measure of it, in terms of Liquid Limit and Plasticity Index is given in Table 7-2 for the four enzyme stabilisers. This clearly reinforces the fact that presence of some clay is essential.

Table 7-2 Requirements for Suitable Materials for Enzyme Stabilisers

Stabiliser	Liquid Limit	Plasticity Index	passing 75µm	passing 425µm	Clay content	Linear Shrinkage
Endurazyme		>8	>20%			
Road Tech 2000		>6		>20%	>6%	3%
Terrazyme	<30%		>15%		>6%	
UBIX 010			>10%			

In addition to the above tests some manufacturers suggests that their products are only effective in certain conditions. Available information, in term soil pH and temperature is listed in Table 7-3. These are considered to be typical of all the enzymes. It is therefore suggested that pH should be in the 7±1 region and the temperature should be between 15 to 50°C.

Table 7-3 pH and Temperature Conditions Suitable for Enzyme Soil Reaction

Stabiliser	pH	Temperature (°C)
Endurazyme		8 to 57
Road Tech 2000	<8	10 to 50
Terrazyme	4.5 to 9.5	>15
UBIX 010		9 to 30

It is essential that all soils to be stabilised with enzymes contain a certain level of humic matter. All the manufacturers assume that the required amount of organic matter is present in all soils as none of them specify any tests to ascertain its amount and type. No information was found about the minimum amount of humic material required for enzyme stabilisation to work successfully.

7.1.4 Application Rate

Most of these stabilisers are supplied as concentrated liquids and have to be diluted before application to soil. Dilution range is typically between 1:150 to 1:300 (stabiliser:water ratio). The guidance given by the manufacturers in most cases relates to the upper and lower limit only. Invariably however they say that advice should be sought from them about the application rates.

7.1.5 Application and Construction Procedure

Application of enzyme based products to soils are essentially similar to that of SPP stabilisers. However, there are some key differences. These are described below.

In some instances just before the soil is compacted and after application of the stabiliser, it is essential that a second compound is added as in the case of UBIX 10. This seals the road surface and prevents it from drying out too rapidly. After the soil is compacted a final fog coating of the stabiliser is applied. The fog coating may be very dilute, up to a ratio of 1:1000 (stabiliser:water). Both Terrazyme and UBIX 010 suggest this. After application of the fog coating it is essential to cure the soil for up to about 72 hours before permitting traffic flow. Thus the enzyme based stabiliser will result in longer road closures than the SPP based stabilisers.

7.1.6 General Discussion

A well graded soil is required for achieving high density. A number of manufacturers refer to this as ability of the soil to "form structure". Once the "structure" is formed the bonds then fix-in-place the compacted particles. Therefore it is essential that soils to be stabilised contain particle sizes ranging from clay to gravel and are well graded. The upper limit will be determined by the thickness of each layer to be compacted. Conventional wisdom is that the largest particle should not be greater than one third the layer thickness but some manufacturers recommend that it should not exceed about 20mm. At the lower end of particle sizes, manufacturers suggested that the clay content should be between 6 and 30%. If the clay content is less then the suggested amount then more clay should be added and mixed with the existing soil before adding the stabiliser. If it is more than 30% then some sand should be added. Larger quantities of stabiliser will be required for materials with higher clay content. Typical concentrations of materials are given in Table 7-4. On average it seems that one litre of stabiliser can be used to treat three cubic metres of soil.

No manufacturers suggest that laboratory tests should be conducted to evaluate the appropriate stabiliser content. It seems that field conditions cannot be replicated in the laboratory adequately to ascertain behaviour of the stabiliser. Field trails are thus recommended. Field trials can however, be expensive and it is therefore suggested that laboratory tests should be conducted in non-standard conditions that replicate those present in the field. Modification will require to curing conditions and period, and loading conditions for instance. This may mean that it is not immediately possible to compare the results from one site with another, but it should enable site specific evaluations to be made with greater degree of confidence prior to conducting expensive field trials.

Table 7-4 Enzyme Stabiliser: Soil Ratios

Stabiliser	Amount of stabiliser to be added (stabiliser:soil)		Fog layer concentration (l/m^3)
	Range (l/m^3)	Average (l/m^3)	
Endurazyme		1.:3.5	
Road Tech 2000	1:2.4 to 1:4	1:3	
Terrazyme		1:2.5	1:1000
UBIX 010	1:28 to 1:30		Required*

* Fog layer required but rate of application data not available

Poorly graded soils should be modified by adding material containing a suitable range of particles. Although some manufacturers claim that materials containing no fines can be stabilised no evidence from case studies was found.

7.1.7 Examples of Enzyme stabilisers

Some proprietary names of enzyme stabilisers are listed below

- ECOCRETE
- Paczyme
- RoadTech 2000
- Terrazyme
- UBIX 010

Further detailed information is given in Appendix I of this report.

7.2 Costs

Where costs are available all the manufacturers claim that it is cheaper to use these products to stabilise soils compared to conventional road construction methods where suitable construction materials would need to be imported. Details of costs are given for each product, where available, in Appendix I.

7.3 Conclusions

A number of compaction aids (sulphonated petroleum products) and binders (enzymes) are available for stabilising soils. For successful realisation of improvements in soil properties all these products require the following: selection of appropriate application rate for the given soil and suitable weather conditions, use of appropriate construction techniques and suitable curing conditions.

Laboratory tests are in general not recommended for evaluation of the stabilisers as standard methods of tests do not reflect field conditions and therefore can give misleading information. Further work is required in to develop appropriate laboratory tests.

All the stabiliser manufacturers claim that use of their products in road construction results in cost savings.

All the product manufacturers claim that products are environmentally friendly. In dilute form they may not present a hazard, but great care is required in storing and handling these products in concentrated form. This applies particularly to sulphonated petroleum products.

It is concluded that these products work but, they can be applied successfully only in certain conditions. It is therefore imperative that the correct stabiliser is chosen.

8. DATABASE

A database comprising 38 synthetic stabilisers (based on petroleum products and enzymes) was compiled. In some instances manufacturers do not reveal the nature of the stabilisers. These products were also included in the database. The contents of the fields of the database are described below and the full database is given in Appendix I. A list of contacts, where available, and addresses of suppliers are given in Appendix II.

8.1 Database Fields

The contents of the database fields are described below.

Field Name	Field Description
Product Information	
Product name	Commercial name of the product
Product description	Description of the physical nature of the product (colour, liquid or solid, odour, etc.)
Active ingredient	Names of key active ingredient where known (enzyme, sulphonated petroleum product, etc.)
Quoted cost	Cost of treatment of soil is quoted where known (£ or $ per m^3).
Quoted performance	performance is quoted in terms of savings in cost, increases in CBR, etc. from case studies or other information provided by the manufacturer.
Uses and Application	
Soil stabilisation	Yes/No
Subbase stabilisation	Yes/No
Waste stabilisation	Yes/No
Dust Control	Yes/No
Surface maintenance	Yes/No
Impermeable liner	Yes/No
Other uses	Uses other than the ones described above are described.
Soil (material) types	From product information or from case studies listed in brackets)
Soil types ( )	Types of soils for which the stabiliser is most useful.
Notes	Additional notes about the materials from case studies.
Technology Limitations	
Limitations	Limitations of use
Environmental Implications	Information about hazards related to the use of the stabiliser.
Non toxic	Blank space means the material is toxic
Non flammable	Blank space means the material is flammable
Non corrosive	Blank space means the material is corrosive
Notes	Other notes about environmental/safety issues relating to the product.
Case Studies	Maximum of two relevant case studies were summarised for each product.

Field Name	Field Description
Technology Limitations, cont...	
Client name	Name of the client for which work was carried out
Client contact	Contact name for information about stabiliser
Site location	Location of the site at which soil stabilisation work was carried out.
Conditions at site	Description of soils treated and any other information about the site.
Results	Description of performance of the stabiliser
Typical costs	Cost of treatment for case study
Conclusions	Conclusions about the stabiliser and case studies.

8.2 Use of Database

The database is included in Appendix I to Report V in an electronic format on compact disc. All the products are listed in alphabetical order.

8.3 Using the Database

The database has information saved in form format using Microsoft Access 97 on the compact disc provided. To access the information go the table of contents, open the directory containing the database (Element D - Appendix I) and follow the on-screen instructions.

Please note that blank fields mean that information was not available.

8.4 Recommendation about the Database.

This database contains information about 38 products. Research has shown that from time to time new products appear on the market and some unsuccessful ones tend to disappear. There is thus a need to keep the information updated. It is therefore strongly recommended that the database is kept updated on am annual basis.

REFERENCES

Bagonza S. (1996) The performance of Sipi-Kapchorwa Road: Uganda's Experience of Conaid-Treated Roads, Conaid, Seminar, Ghana.

Paige-Green, P. and Coester K. (1999) Towards successful SPP Treatment, CSIR, Report No. RR93/186.

Scherr, G.A. 1999 Waste Management - A Future Challenge for the protection of Mineral Resources. 2nd European Conference on Mineral Planning 'ECMP 99', Harrogate, England.

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Report V - Appendix I
Review of Soil Stabilisation Methods

DFID Department for International Development

February 2000

Appropriate and Efficient Maintenance of Low Cost Rural Roads

Report V - Appendix I
Report V: Review of Soil Stabilisation Methods

February 2000

The University of Nottingham
School of Civil Engineering
University Park
Nottingham
NG7 2RD
United Kingdom
www.nottingham.ac.uk/p&g

Roughton International.
321 Millbrook Road West
Southampton
SO15 OHW
United Kingdom
www.roughton.com

University of Birmingham
School of Civil Engineering
Edgbaston
Birmingham
B15 2TT
United Kingdom
www.bham.ac.uk/CivEng/

DFID Department for International Development

Department for International Development
94 Victoria Street
London
SW1E 5JL
www.dfid.gov.uk

Department for International Development
Knowledge and Research (KaR) Programme

Project Title:	Appropriate and Efficient Maintenance of Low Cost Rural Roads
DFID Project Reference:	R6852
Subsector:	*Transport*
Theme:	T2
Element D:	Investigation of Stabilisation Methods
Date:	*February 2000*

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CLICK HERE TO OPEN DATABASE

Database Containing
CHEMICAL SOIL STABILIZER INFORMATION

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Report V - Appendix II
Review of Soil Stabilisation Methods

DFID Department for International Development

February 2000

Appropriate and Efficient Maintenance of Low Cost Rural Roads

Report V - Appendix II
Report V: Review of Soil Stabilisation Methods

February 2000

The University of Nottingham
School of Civil Engineering
University Park
Nottingham
NG7 2RD
United Kingdom
www.nottingham.ac.uk/p&g

Roughton International.
321 Millbrook Road West
Southampton
SO15 OHW
United Kingdom
www.roughton.com

University of Birmingham
School of Civil Engineering
Edgbaston
Birmingham
B15 2TT
United Kingdom
www.bham.ac.uk/CivEng/

Department for International Development
94 Victoria Street
London
SW1E 5JL
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Department for International Development
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1. LIST OF SUPPLIERS

PRODUCT: Base-Seal

Company: Base-Seal International Ltd.
Address: 15822 River Roads
Houston
TX 77079
Telephone: 713-497-7743
Fax: 713-497-1345
Web-Page: http://www.abuildnet.com/users/000171.html
E-mail: baseseal@juno.com

PRODUCT: B.C.Stabilizer

Company: California-Fresno-Oil
Address: PO Box 527
Fresno
Ca 93709
USA
Telephone: 209-486-0220
Fax: N/A
Web-Page: http://www.calfresno.com/bcstab.html
E-mail: calfres@cybergate.com

PRODUCT: Calbinder

Company: California-Fresno-Oil
Address: PO Box 527
Fresno
Ca 93706
USA
Telephone: 209-486-0220
Fax: NA
Web-Page: http://www.calfresno.com/bcstab.html
E-mail: calfres@cybergate.com

PRODUCT: Condor

Company: Earth Science Products
Address: P.O.Box 327
Wilsonville
OR 97070
Telephone: 503-678-3370
Fax: 503-678-3374
Web-Page:
E-mail: prochem@cyberramp.net

PRODUCT: Ecocrete

Company: Global Eco Products Inc.
Address: 1800 E.Sahara, Suite 107
Las Vegas
Nevada 89104
USA
Telephone: 1-310-372-6822
Fax: 1-310-379-0085
Web-Page: http://www.ecocrete.com/
E-mail: eco@ecocrete.com

PRODUCT: Ecotec

Company:
Address: Unknown
Telephone:
Fax:
Web-Page:
E-mail:

PRODUCT: 2001 Polymeric Asphalt

Company: Enviroseal Corporation
Address: 5309 Lake Worth Road
Lake Worth Fl 33463
Telephone: 561-641-0400
Fax: 561-641-8731
Web-Page: http://www.enviroseal.com
E-mail: soils@enviroseal.com

PRODUCT: LBS

Company: Enviroseal Corporation
Address: 5309 Lake Worth Road
Lake Worth
Fl 33463
Telephone: 561-641-0400
Fax: 561-641-8731
Web-Page: http://www.enviroseal.com
E-mail: soils@enviroseal.com

PRODUCT: LDC

Company: Enviroseal Corporation
Address: 5309 Lake Worth Road
Lake Worth
Fl 33463
Telephone: 561-641-0400
Fax: 561-641-8731
Web-Page: http://www.enviroseal.com
E-mail: soils@enviroseal.com

PRODUCT: LAS-320 Asphalt Sealer

Company: Enviroseal Corporation
Address: 5309 Lake Worth Road
Lake Worth Fl 33463
Telephone: 561-641-0400
Fax: 561-641-8731
Web-Page: http://www.enviroseal.com
E-mail: soils@enviroseal.com

PRODUCT: ISS 2500

Company: Road Material Stabilisers (Pty) Ltd.
Address: PO Box 84513
Greenside 2034
Johannesburg
South Africa
Telephone: 27-11-646-3713
Fax: 27-11-646-3713
Web-Page: http://www.iss2500.co.za/index.html
E-mail: iss@global.co.za

PRODUCT: Hifa Bond

Company: Dgi Ltd. (Address Is Of Dr.S.Zou)
Address: Dept.Mining And Met.Engineering
Dal Tech
Dalhousie University
1360 Barrington Street
Halifax NS
Canada B3J 2X4
Telephone: 902-494-3977
Fax: 902-425-1037
Web-Page:
E-mail: steve.zou.dal.ca

PRODUCT: Permazyme

Company: Pacific Enzymes Inc.
Address: 2015 Rockwood Drive
Sacramento
CA 95864
Telephone: 916-488-0939
Fax: 001-1-916-488-1128
Web-Page:
E-mail: lreynold@netside.com

PRODUCT: Pro-Base

Company: Pro-Base International
Address: Singapore
Telephone: 65-442-2417
Fax: 65-446-6470
Web-Page:
E-mail: probase@pacific.net.sg

PRODUCT: Gluon-240

Company: Rainstorm Dust Control (Pty) Ltd.
Address: Unknown
Telephone: 08-9455-4680
Fax: 08-9455-4681
Web-Page: http://www.rainstorm.com.au/gluon240.htm
E-mail: gregkerr@rainstorm.com.au

PRODUCT: Pac-Zyme

Company: Rainstorm Dust Control (Pty) Ltd.
Address: Unknown
Telephone: 08-9455-4680
Fax: 08-9455-4681
Web-Page: http://www.rainstorm.com.au/paczyme.htm
E-mail: gregkerr@rainstorm.com.au

PRODUCT: Roadbond E-N-One

Company: C.S.S Technology Inc.
Address: PO Box 1355
Weatherford
Texas 76086
Telephone: 817-598-0997
Fax: 817-598-0999
Web-Page: http://www.csstech.com/forest.htm
E-mail: cssten1@csstech.com

PRODUCT: Roadtech 2000

Company: Road Technologies International Pty Ltd.
Address: PO Box 2360
Burleigh Mdc 4220
Queensland
Australia
Telephone: 07-5576-6490
Fax: 61-7-5576-6493
Web-Page: http://www.roadtech.com.au/lo-tech/lowindex.html,
E-mail: info@roadtech.com.au

PRODUCT: Romix Sandcote

Company: Romix Industries
Address: South Africa
Telephone:
Fax:
Web-Page:
E-mail: romixint@hotmail.com

PRODUCT: RRP (Reynolds Road Packer)

Company: C H Non-Food Import-Export Corp.
Address: Pasea Estate
Road Town
British Virgin Islands
Telephone: Tel: +356 585571
Fax: +356 583640
Web-Page: http://www.ch-non-food.com/special.htm
E-mail: trade@ch-non-food.com

PRODUCT: Roadamine

Company: Instituicao Particular De Solidariedade Social
Address: Apt.80
8550 Monchique
Portugal
Telephone: 351-82-912719
Fax: 351-82-913816
Web-Page:
E-mail: inpeco@mail.telepac.pt

PRODUCT: Con-Aid (Also Known As CBR Plus)

Company: CBR PLUS, LLC.
Address: PO Box 230761
Portland, OR 97281
USA
Tel/ Fax: **(503) 644-2207**
Cell: **(503) 476-5262**
Web-Page: http//www.cbrplusllc.com
E-mail: **cbrplusllc@yahoo.com**

PRODUCT: Consolid

Company: Consolid Ag, Schnaren
Address: Ch-9467 Frumsen Sg
Switzerland
Telephone: 41-81-757-1686
Fax: 41-81-740-4150
Web-Page:
E-mail:

PRODUCT: Descobond 500 (DB500)

Company: California-Fresno Oil
Address: 3242 E. Garrett
Fresno
CA 93706
USA
Telephone: 559 486-0220
Fax:
Web-Page: http: //www.calfresno.com/descobon.html
E-mail: calfres@cybergate.com

PRODUCT: Pennzsuppress - D

Company: Pennzoil Products Company
Address: Unknown
Telephone:
Fax:
Web-Page: http://www.pennzsuppress.com
E-mail: pnzind@infosol.com

PRODUCT: Emc Squared/Ems

Company: Soil Stabilization Products Company Inc.
Address: PO Box 2779
Merced
CA 95344
USA
Telephone: 209-383-3296 / 800-523-9992
Fax: 209-383-7849
Web-Page: http://www.sspco.org/expansiveclay.html
E-mail: staff@sspco.org

PRODUCT: Supersol

Company: Saftra House (Pty) Ltd.,
Address: PO Box 41332
Craighall 2024
South Africa
Telephone: 00-27-11-444-7047
Fax: 00-27-11-444-4722
Web-Page: http://www.supersol.com/
E-mail: saftra@global.co.uk

PRODUCT: Terrazyme

Company: Concord (Usa) Ltd.
Address: Dept. Cn
1300 Sumter Street
PO Box 11529
Columbia
South Carolina 29211
Telephone: 803-254-0600
Fax: 803-799-9895
Web-Page:
E-mail: rhwcusa@aol.com

PRODUCT: Terrabond

Company: Fluid Sciences
Address: PO Box 81338
Lafayette
La70598-1338
Telephone: 318-264-9448
Fax: 318-261-0326
Web-Page: http://www.fluidsciences.com/terrabond.htm
E-mail: info@fluidsciences.com

PRODUCT: Top-Seal

Company: Soils Control International Inc.
Address: 1711 East Central Texas Expressway
Killeen
Texas, 76541
Telephone: 254-556-5550
Fax: 254-554-5999
Web-Page:
E-mail: myoung@soilscontrol.com

PRODUCT: TX-55

Company: Specialist Construction Services Pte Ltd.
Address: 2 Finlayson Green
14-06 Asia Insurance Building
Singapore 049247
Telephone: 65-241-7964
Fax: 65-446-0449
Web-Page:
E-mail: roads@specialist.com.sg

PRODUCT: Soil-Pac

Company:
Address: Unknown
Telephone:
Fax:
Web-Page: http://abr.net/clients/soilpac/
E-mail: abr@ion.com.au

PRODUCT: Endurazyme 388

Company: World Enzymes Australia, A Division Of Mitebridge Pty Ltd,
Address: PO Box 428
Toowong
Brisbane
Australia 4066
Telephone: 64 07 3871 0508
Fax:
Web-Page: http://www.ozemail.com.au/~quadron/roadfrme.htm
E-mail:

PRODUCT: Ubix 010

Company: Enzymes Plus , Anderson Affiliates Inc.
Address: 1451 Sugar Creek Blvd
Sugar Land
Texas
USA
Telephone: 281 242 7741
Fax: 281 242 7816,
Web-Page: http:// www.ibicorporation.com
E-mail: ubixenzyme@aol.com